Ministry of
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Ontario

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FROST SUSCEPTIBILITY STUDY OF GRANULAR 'A'

MATERIALS INFORMATION
ENGINEERING MATERIALS OFFICE

FROST SUSCEPTIBILITY STUDY

OF GRANULAR 'A'

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1. INTRODUCTION

Recently, the B.C. Ministry of Transportation and Highways reduced the maximum allowable pass 75 um content from 9% to 5% for their granular base and subbase materials. One of their research findings suggested that granular materials with a high percentage of fines are frost susceptible.

Heave is one form of frost action that can have damaging effects on flexible pavements. The formation of ice lenses within the base, subbase and subgrade will cause a vertical deflection of the upper pavement layers. Stresses in the pavement are produced causing cracking and surface distortion.

Further problems occur during the spring thaw. The melting of the ice lenses releases free water within the base, subbase and subgrade resulting in saturated conditions. Cyclic wheel loadings on the weakened pavement structure leads to cracking and premature pavement break-up.

In view of the impending consequences that can arise from frost action, it is important to ensure that granular materials are of a non-frost susceptible nature.

Presently, the MTC allows up to 8% fines content for granular materials (10% for quarried material or slag), although this limit has not been evaluated with regard to frost heaving characteristics.

A limited laboratory test program was conducted to evaluate this limit with respect to frost heaving.

2.0 GENERAL

In this laboratory study, Granular 'A' materials with varying pass 75 um content were tested in a frost heave apparatus to evaluate the frost heaving potential. The frost heave data was compared to the test method criteria to estimate the frost susceptibility of the various granular gradations.

The laboratory test procedures used in this study were closely adapted from the Transport Road and Research Laboratory (T.R.R.L.) test method for the frost heave testing of granular materials. This method was selected for several reasons:

(i) it was specifically developed for granular materials

(ii) the testing time specified (96 hours) was more practical in comparison to other test methods which specify testing time durations up to 250 hours.

2.1 TEST GRADATIONS

The 1983 provincial mean gradation for pit run and quarried Granular 'A' served as the basis of each test gradation used in this study. In order to study the effects of fines content on the frost susceptibility of the material, both gradations were modified by varying the percentage of fines from 0% to 15% in 3% increments. Figures 1 and 2 show the grain size distribution curves for the twelve test gradations.

2.2 SAMPLE COLLECTION AND PREPARATION

Granular 'A' quality material was obtained from two commercial suppliers. Approximately 250 Kg of aggregate was sampled from existing stockpiles at a limestone quarry as well as a sand and gravel operation, both located northwest of Metropolitan Toronto.

The bulk samples were oven-dried and sieved through the following coarse aggregate sieves: 26.5 mm, 19 mm, 13.2 mm, 9.5 mm and 4.75 mm. The fine aggregate passing the 4.75 mm sieve was separated on the 2.36 mm, 1.18 mm, 600 um, 300 um, 150 um and 75 um sieves. The material was placed in separate bags and later washed to remove all pass 75 um fines.

The separated material was then recombined according to the test gradation required.

For each test gradation, a 7 Kg Proctor sample, a 3 Kg trial sample and three 3 Kg frost-heave test samples were needed.

Atterberg limit tests performed on the pass 425 um material in each test gradation indicated that the fines were non-plastic.

Upon completion of the sample processing, One-Point Proctor tests were performed on the 7 Kg samples to establish the maximum dry density and optimum moisture content for each test gradation. This data was required to determine a moisture content at which to prepare the actual frost heave specimens. The Proctor data is shown in Figure 3.

The 3 Kg trial samples prepared for each test gradation were compacted at their optimum moisture content in accordance with the Standard Proctor procedure. If the trial specimen was free standing after extrusion from the Proctor mold, the actual frost heave specimens were also compacted at the optimum moisture content. Collapse of the trial specimen after extrusion would indicate that the optimum moisture content was not sufficient to produce a stable specimen. In this case, the moisture content would be increased.

By conducting this trial exercise, it was established that the optimum moisture content corresponding to each test gradation produced stable, free-standing specimens and therefore modifications to the optimum moisture contents were not necessary.

3.0 PREPARING THE FROST HEAVE TEST SPECIMENS

Each 3 Kg frost heave test sample was compacted at its optimum moisture content using the Standard Proctor procedure. Prior to compaction, a 1 mm

thick flexible plastic sleeve was placed inside the mould. This sleeve provided an annular space between the test specimen and the frost heave specimen holder to prevent build up of adfreeze which would inhibit the heaving of the specimen.

Upon completion of compaction, the specimen was extruded and the sleeve was removed. The curved surface of the specimen was wrapped with petroleum jelly-coated plastic wrap ensuring that one edge of the plastic wrap was in line with the top of the specimen.

The test specimen was inserted into a cylindrical holder, fabricated from acrylic tubing, 6 mm in thickness. The base of the holder consisted of a perforated acrylic disc. A disc of geotextile was placed between the end of the specimen and the base to minimize the loss of fines through the acrylic disc. At the same time, the geotextile allowed water to rise freely into the specimen.

A metal disc was centrally placed on top of each specimen as a reference point for frost heave measurements.

Each completed test sample was then placed in a shallow pan containing water approximately 2.5 cm in depth and allowed to soak for 24 hours. Figures 4 and 5 show the finished test specimens prior to testing.

4.0 THE FROST BOX

The frost box used in this laboratory study was furnished by the Ontario Hydro Research Division Laboratories. Figures 6 through 8 show details of its construction.

The box was constructed from 1.3 cm thick plywood and lined with 2.5 cm thick polyurethane. A galvanized steel pan was placed at the bottom of the box. The pan contained water which was maintained at a constant temperature of + 4°C by means of a heating cable connected to a thermal regulator.

The test specimens were inserted through an 8 cm thick layer of polyurethane which was fitted on top of the galvanized steel pan. The polyurethane served several functions:

(i) it prevented heat transfer between the specimens, thus ensuring that a one-dimensional temperature gradient was applied to the specimens.
(ii) it provided insulation between the pan of water and the freezing temperatures above.
(iii) it provided confinement for the specimen holders.

5.0 FROST HEAVE TESTS

The frost heave tests were conducted in a walk-in freezer. Initial height measurements were taken with a dial gauge and subsequent heave readings were taken twice daily.

The specimens were left in the freezer for 96 hours prior to removal. The ambient air temperature within the walk-in freezer was maintained at -17°C while the water bath in which the specimens rested was maintained at + 4°C.

6.0 DISCUSSION OF TEST RESULTS

The mean frost heave for each test gradation was calculated from data obtained from the four test series conducted. These results have been plotted and are shown in Figures 9 and 10.

The graphs clearly show an increase in mean heave as the fines content increases. This increase would be due to an increase in capillary action corresponding to the increase in fines. Furthermore, each test gradation composed of pit run Granular 'A' heaved more than the corresponding quarry gradation with an equivalent fines content. This could be attributed to the slightly finer pass 4.75 mm gradation of each pit run material. Also, the particle shape of a crushed material would tend to produce a 'locking' action and the irregular void shape less capillary rise, thus accounting for less heave.

In classifying each test gradation in terms of its frost susceptibility the T.R.R.L. test method provides frost susceptibility criteria. These criteria were developed from tests made on granular materials whose heaving performance in the field was known. The criteria categorize each test gradation as "non-frost susceptible", "frost susceptible" or "not proven" based on the mean of the three maximum heaves. If the mean of these maxima place the material in a "not proven" category, additional specimens should be tested. For this study, time and material restrictions did not permit this additional testing.

The modified T.R.R.L. classification system is shown in Figure 11. The T.R.R.L. test method specifies the height of the test specimen to be 152.4 mm where as the specimen tested in this study were 116.3 mm. In view of this difference, the classification system was modified by multiplying the heave in each category by a factor of 116.3/152.4.

The current MTC specification for quarried Granular 'A' limits the percentage of fines to a maximum of 10%. Figure 12 shows that a fines content of 10% or less produces a non-frost susceptible material. For the pit run test gradations shown in Figure 13, a fines content of 7.5% or less will render the material non-frost susceptible.

7.0 CONCLUSIONS

One test method used to estimate the frost susceptibility of granular materials has been performed in this limited laboratory study. The experimental data tends to indicate that the MTC Granular 'A' specification for fines content provides for a non-frost susceptible granular material, according to the T.R.R.L. Frost Heave Test.

REFERENCES

MTC, EM-42; Alan Hanks; 1980, Frost Heave Measurements of Lime-Modified Soil from the Ottawa Area in the Laboratory.

Transport and Road Research Laboratory; P.G. Roe and D.C. Webster; 1984 Specification for the T.R.R.L. Frost-Heave test.

Harold Atkins, 1963; The Effect of Fines on Flexible Pavement Base Courses.

H.B. Sutherland, P.N. Baskin; 1973, A Comparison of the T.R.R.L. and C.R.R.E.L. Tests for the Frost Susceptibility of Soils.

APPENDIX

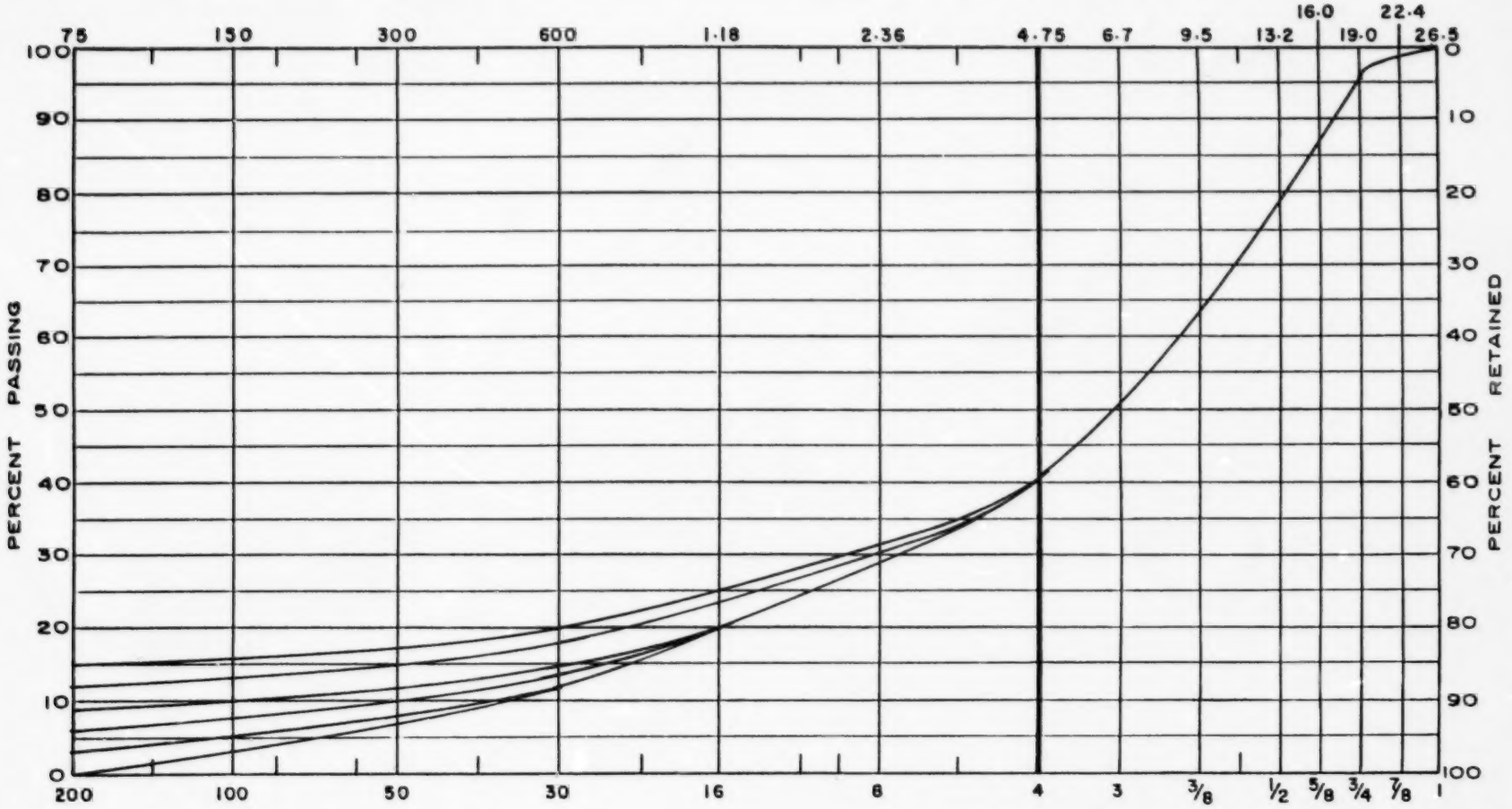


FIGURE 1: Test Gradations (Quarried Granular 'A')

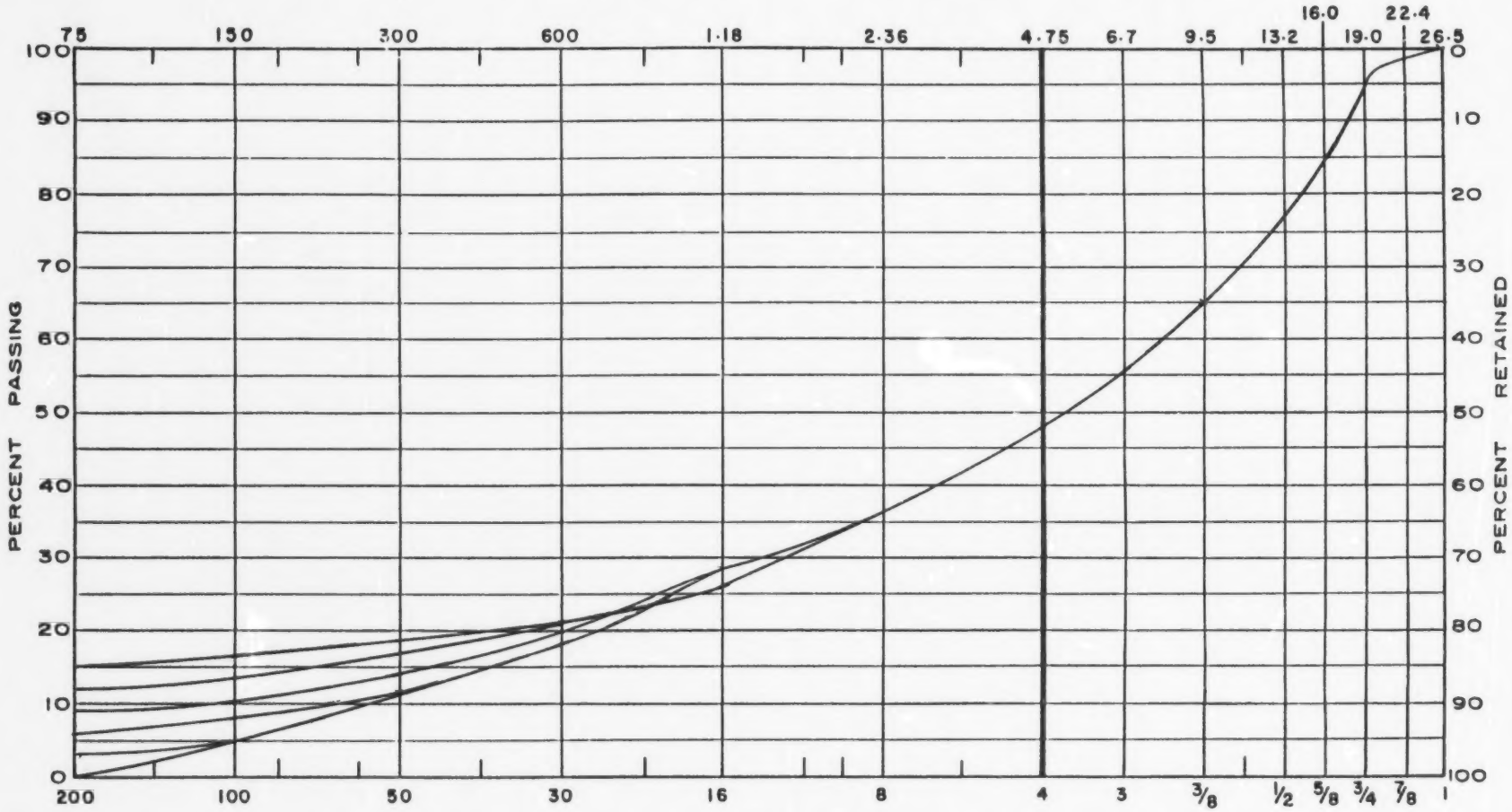


FIGURE 2: Test Gradations (Pit-Run Granular 'A')

% Fines	0	3	6	9	12	15
Optimum Moisture Content (%)	8.0	7.7	7.2	7.0	6.8	6.5
Maximum Dry Density (g/cm^3)	2.143	2.185	2.238	2.273	2.345	2.420

a) Quarried Material

% Fines	0	3	6	9	12	15
Optimum Moisture Content (%)	8.3	7.5	7.2	6.8	6.7	6.6
Maximum Dry Density (g/cm^3)	2.125	2.200	2.245	2.330	2.345	2.355

b) Pit Run Material

Figure 3. Proctor Compaction Results for Each Test Gradation.

FIGURE 4: Frost Heave Test Specimen

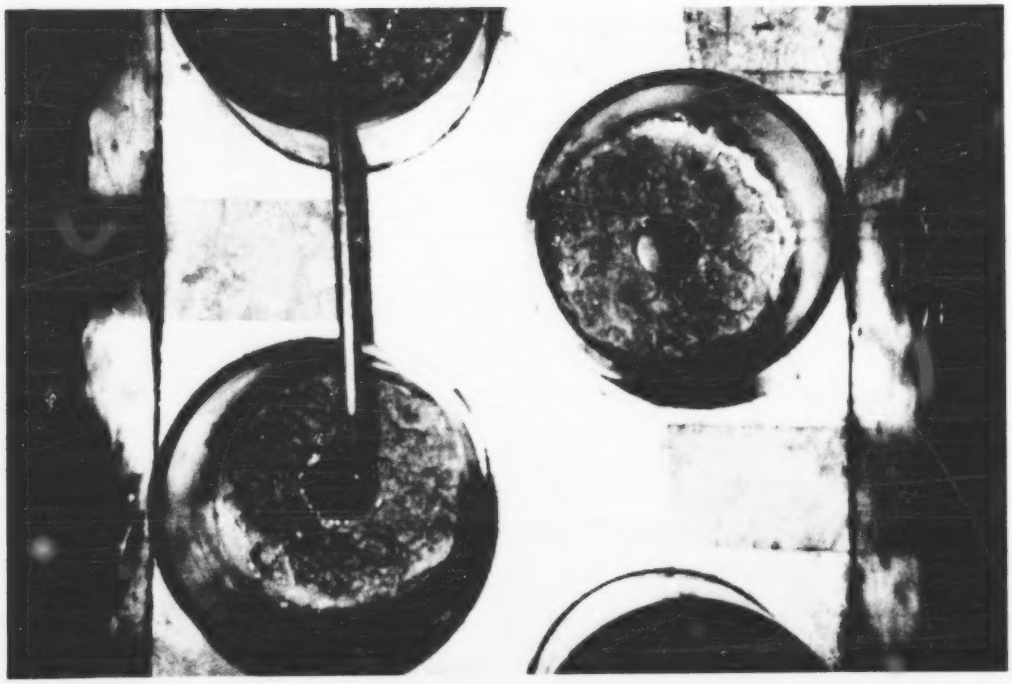
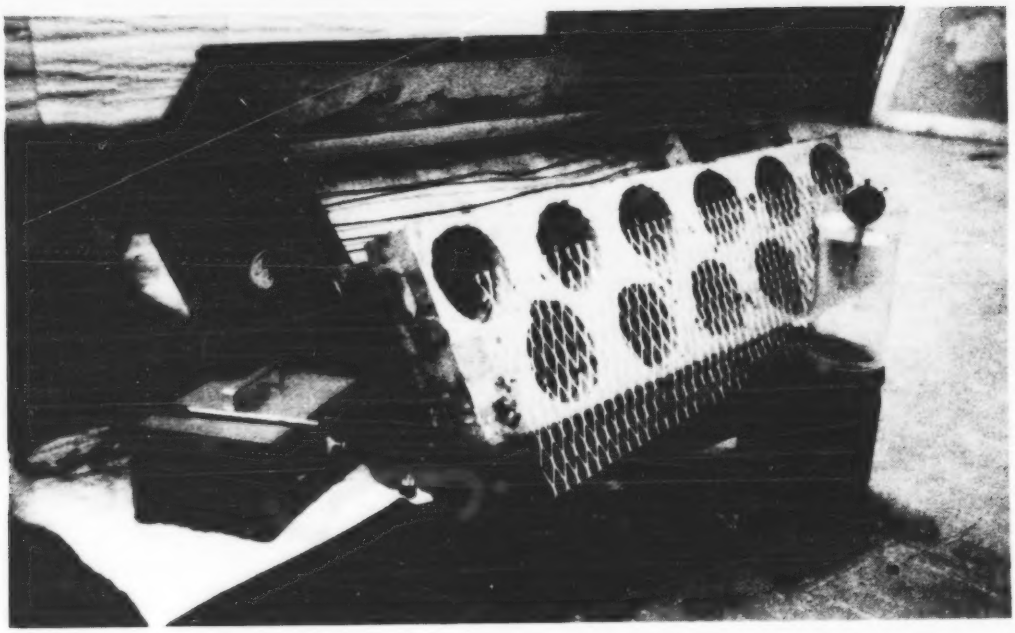
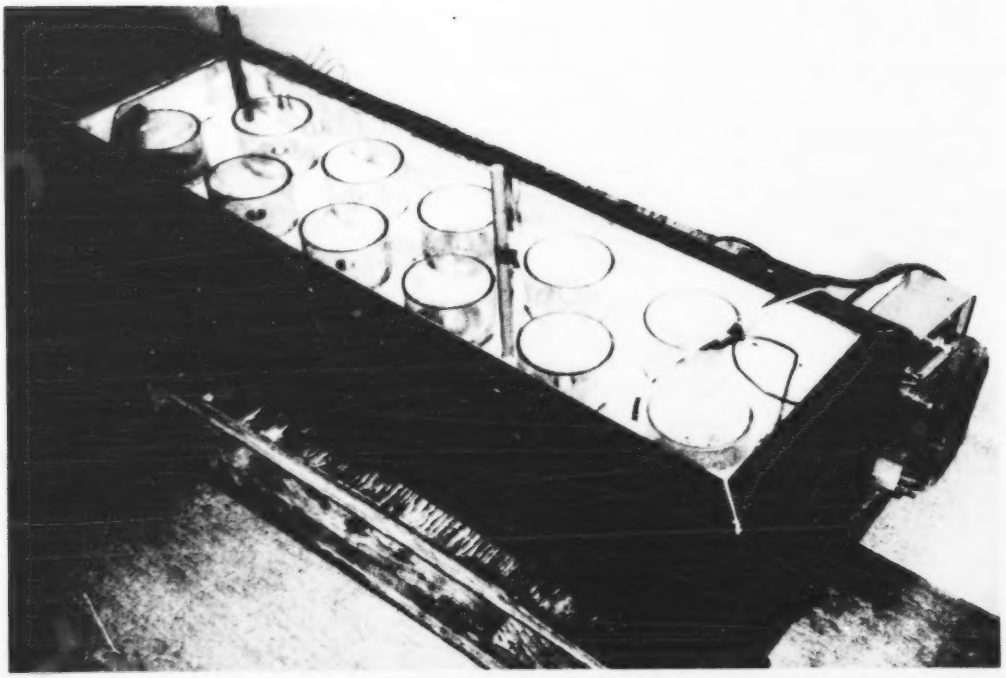


FIGURE 5: Specimen in Frost Box

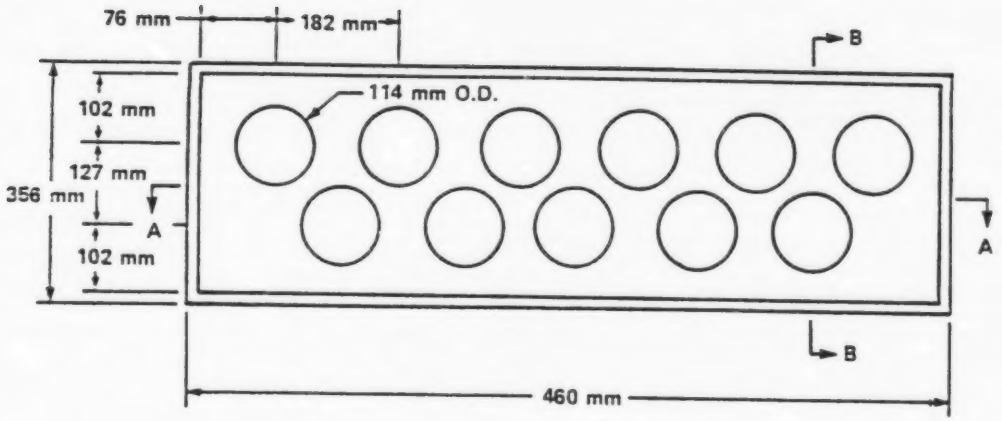


Disassembled

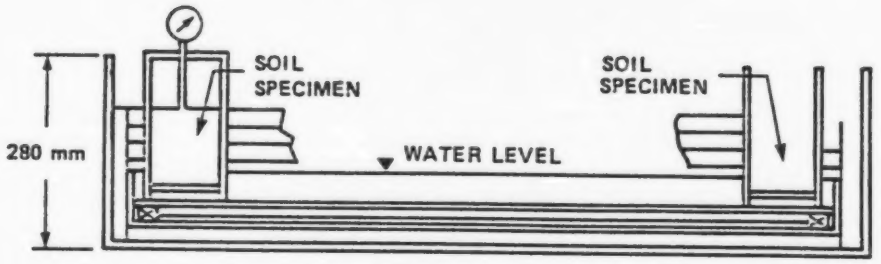


Assembled

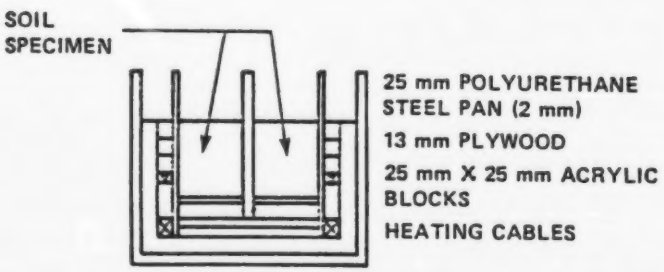
FIGURE 6: The Frost Box



PLAN



SECTION A–A



SECTION B–B

FIGURE 7: Frost Heave Box

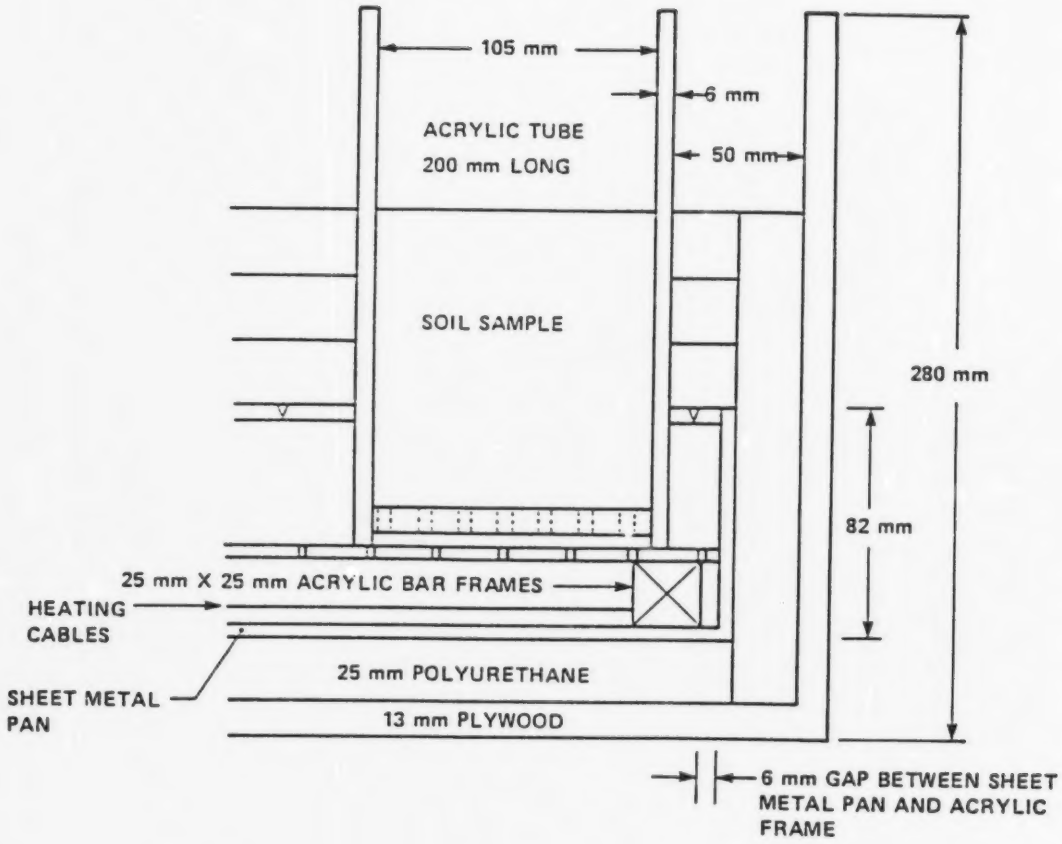


FIGURE 8: Frost Heave Box (Detail)

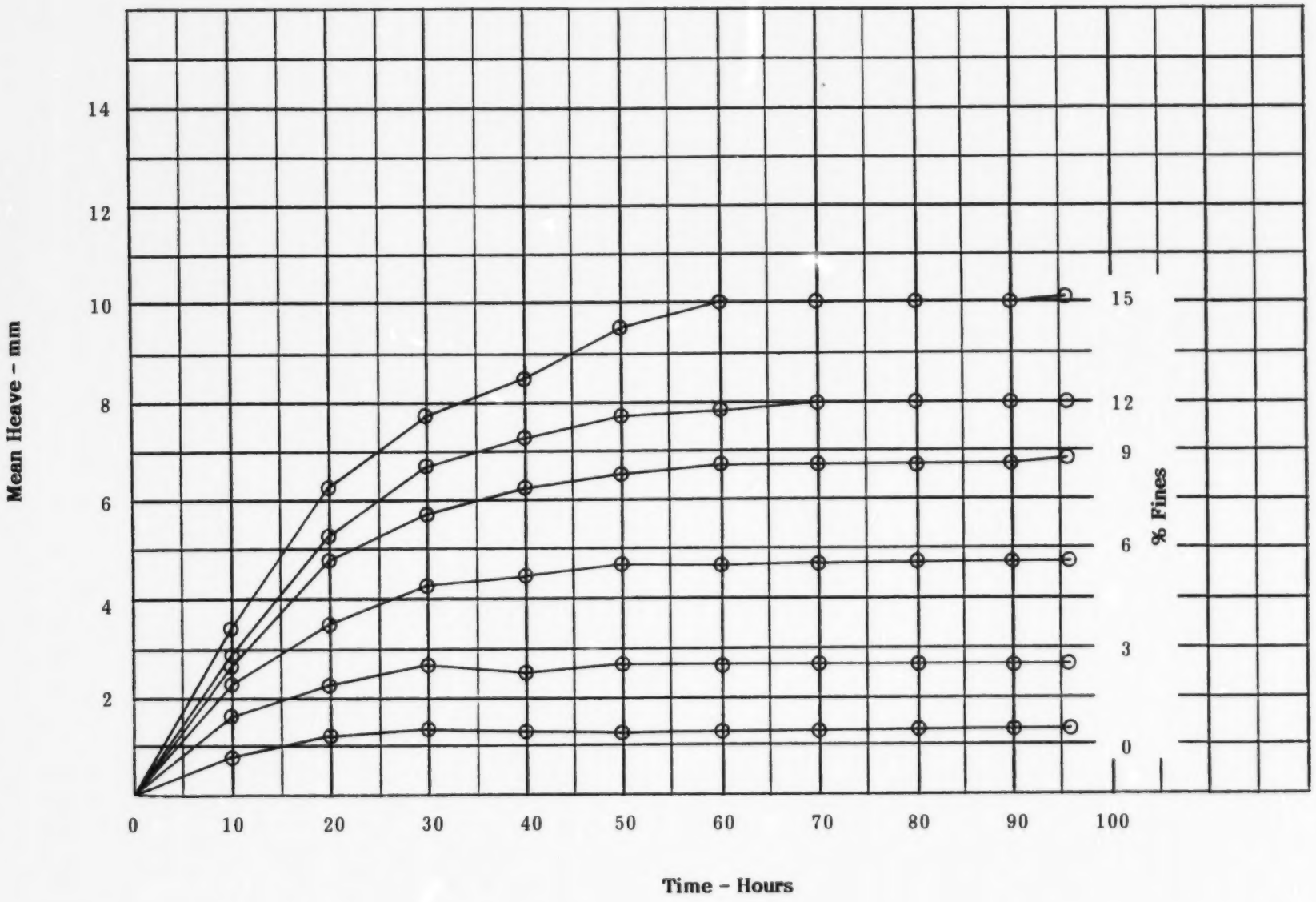


FIGURE 9: Frost Heave Data (Quarried Granular 'A')

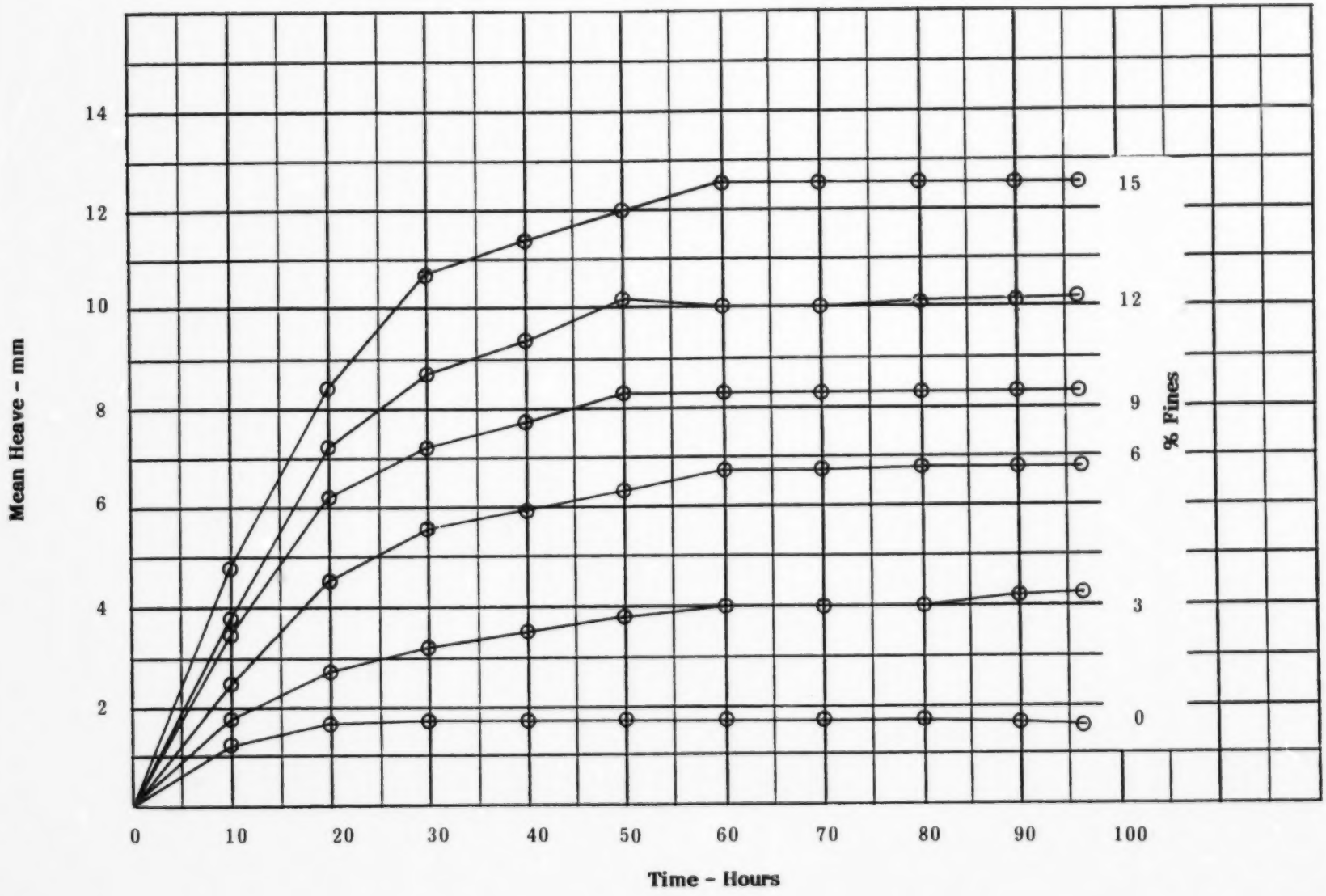


FIGURE 10: Frost Heave Data (Pit Run Granular 'A')

Heave Magnitude - mm	Classification
< or = 6.9 mm	Not Frost Susceptible
> or = 11.4 mm	Frost Susceptible
6.9 to 11.4 mm	Borderline

Figure 11. Modified T.R.R.L. Classification System

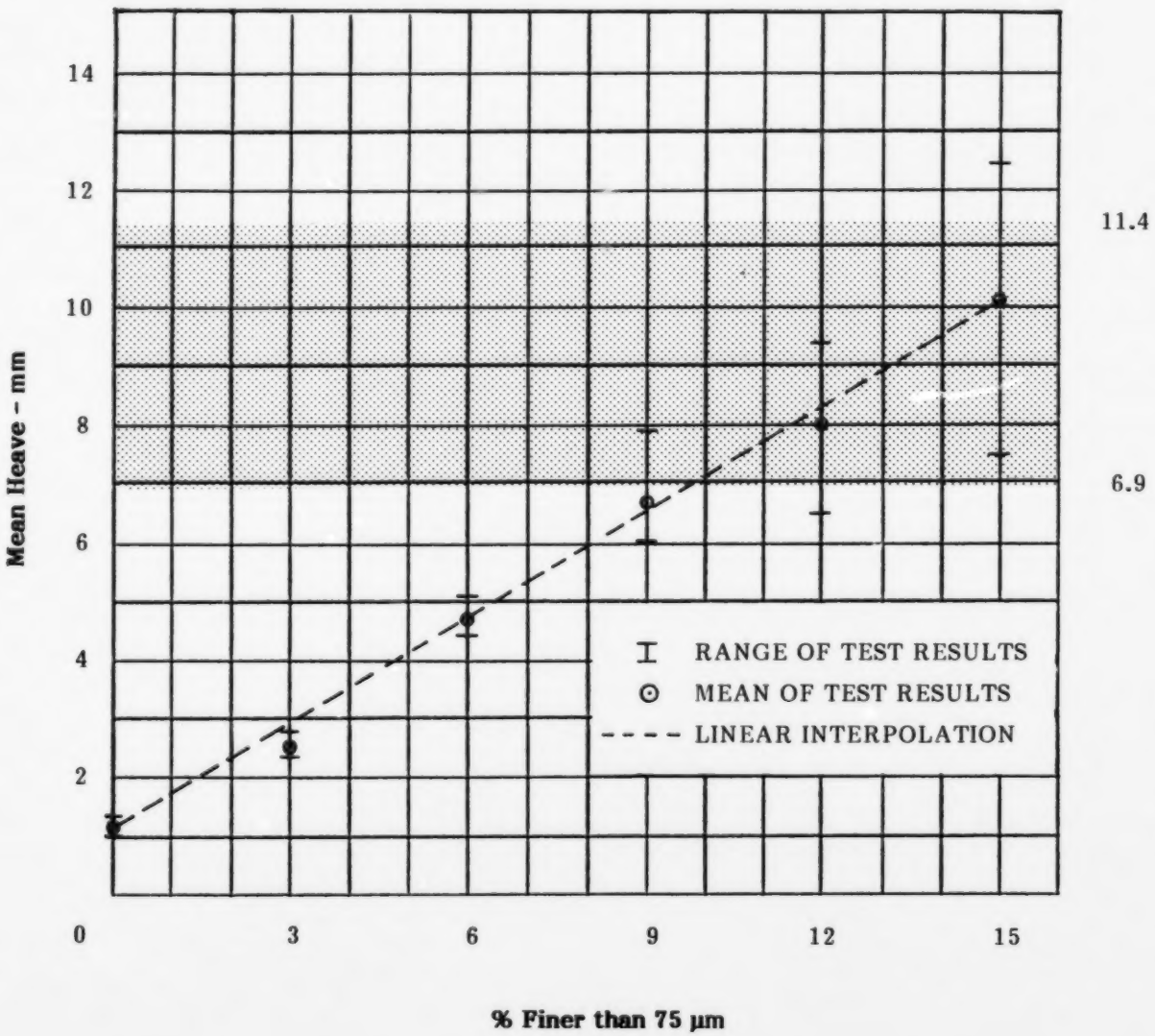


FIGURE 12: Frost Heave Data (Quarried Granular 'A')

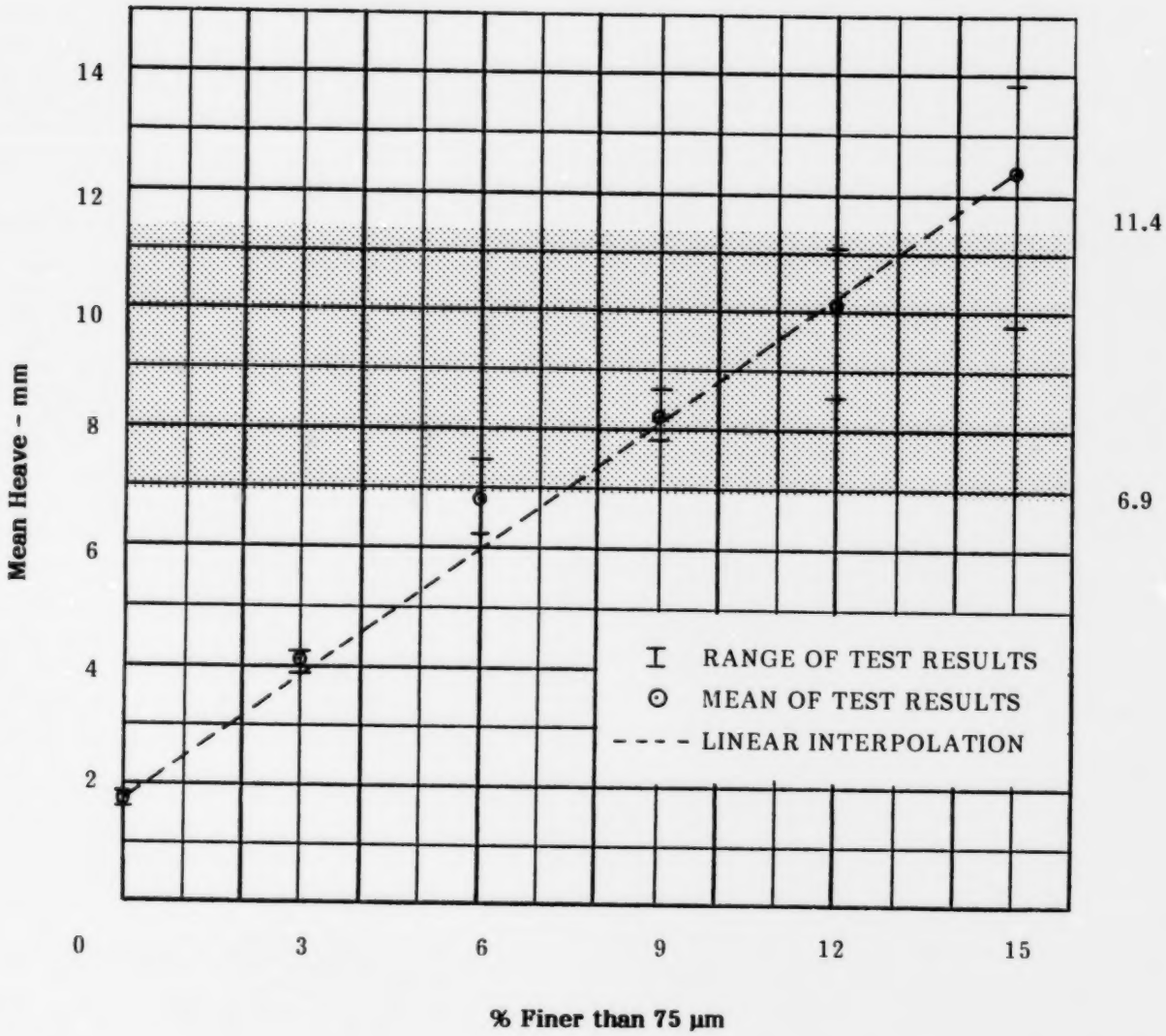


FIGURE 13: Frost Heave Data (Pit Run Granular 'A')